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BRAIN STEM EVOKED RESPONSES IN ALTERED G ENVIRONMENTS (U)

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FOR THE COMMANDER

CHARLES BATES, JR.
Director, Human Engineering Division
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Due to the importance of the vestibular system in both ground-based and space-based motion sickness, a method of measuring its activity in intact humans is desirable. Since the gravitoinertial end-organ receptors of the vestibular and auditory systems are in close proximity and share common peripheral structures, it is hypothesized that changes in the neuroelectrical activity of the otolith pathway affected by gravitoinertial off-loading could possibly influence nerve conduction in the auditory system. This could subsequently be measured by recording changes in the brain stem evoked response (BSER), providing an indirect measure of vestibular activity. BSERs were recorded from ten subjects under the cardinal static environments of +1 and -1 Gx, Gy, and Gz. No changes were found in the latencies of BSER components resulting from the altered G conditions. The gravitoinertial vestibular end organs and the auditory system were not found to interact under the conditions of this study.

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PREFACE

The purpose of this study was to determine if the brain stem evoked response could be used to monitor the effects of vestibular activity during G maneuvers. This is one of several studies that we designed to test the utility of brain evoked electrical activity to study motion sickness. The goal of this study was to determine if the easily measured auditory responses could be used as an index of vestibular activity which is much more difficult to record. This study then deals with the interaction of the auditory and vestibular systems. Another study, which has been reported at an AGARD Symposium, was designed to measure the evoked activity elicited by actual motion of human subjects.

The results of this study show no effect on the brain stem evoked response due to body orientation, but it is nevertheless important that these results be reported. Others may use the same logic and perform a similar study and not report their results.

INTRODUCTION

Since the vestibular system plays a principal role in the development of ground based motion sickness and has been implicated in the space motion sickness (SMS) experienced by astronauts, a method of measuring its electrical activity is desirable. If a suitable method of electrical measurement could be found, it is hypothesized that a better understanding of multi-sensory brain signal integration would be appreciated and a greater opportunity for intervention obtained. A comprehensive look at the various aspects of the neurovestibular system was, therefore, initiated. This included recording brain electrical activity evoked by body motion and evoked by electrical stimulation of the vestibular apparatus. The results of the study in which cortical evoked potentials were evoked during a dynamic state of angular acceleration have been reported previously (12). The study reported here principally seeks to measure the activity of otolith off-loading by recording evoked responses to auditory stimuli.

Because the peripheral receptors of the vestibular system and acoustic system share common endolymph through connecting ducts (7), it was hypothesized that it might be possible to measure the neural effects of otolith off-loading by measuring brain stem evoked responses (BSER) through the acoustic nerve. This would provide an indirect measure of otolith activity. Thorton attempted to obtain similar information aboard the Space Shuttle during STS-4 (11).

Since non-neural electrical signals from cochlear implanted electrical prostheses have been reported to interfere with postural stability by some authors (1, 2), albeit not others (4), it was conjectured that an off-loading of the otolith might cause a significant enough disruption in baseline neural signal integration to result in changes in acoustic nerve propagation times. If this were true, and since it has been difficult to measure the electrical events associated with vestibular activity in intact humans, it would be of great value to estimate vestibular activity via the more easily measured electrical activity of the auditory system. It is possible to record the electrical activity of the auditory system that occurs in the brain stem during the 10 msec following acoustic stimulation, i.e., the BSER (8). By using the BSER one can identify electrical activity at the various stages of transmission of auditory signals through the brain stem. At least seven components of the BSER have been identified, and each has been associated with the electrical activity of brain structures from the auditory nerve to the thalamocortical pathways. This suggest the possibility that interaction between auditory and vestibular systems could be detected by recording the electrical activity at these very early stages of information processing.

Studies from this laboratory have investigated this hypothesis and have presented conflicting results. Harsha (5) did not find changes in the BSER immediately following stimulation of the semicircular canals of subjects who were spun in a Barany chair. The subjects were spun at different rates, and clicks were applied immediately thereafter via earphones and the BSER recorded. No significant differences in the BSER were found as a result of the angular acceleration. Wolf et al (13,14) used a different strategy using caloric stimulation. Immediately following irrigation of the external auditory canals, the BSER was measured. Changes were observed in the BSER between baseline and caloric stimulation. However, due to the anatomy of the inner ear, the temperature of both the vestibular and auditory apparatus was changed. Since it has been observed that the small change in body temperature due to diurnal fluctuations can significantly change the BSER, it is possible that the BSER changes were due entirely to local temperature effects and not to interaction with concurrent vestibular activity (9).

More recently, Cullen et al reported significant latency increases in the BSER immediately following optokinetic stimulation (3). This study demonstrates the possible interactions among various components of the oculovestibular and auditory pathway.

This study was designed to permit the recording of auditory responses while subjects were concurrently experiencing altered gravitoinertial (G) states for short periods. These tests were therefore designed to measure the effects of altered static G states on the otolith of the maculae, and not the effects of angular acceleration on the semicircular canals. Plus and minus 1G in three axes were used to test for changes in the BSER due to changes in vestibular activity.

METHODS

The subjects were eight male adults, chosen from the Armstrong Aerospace Medical Research Laboratory (AAMRL) Dynamic Environment Simulator (DES) subject pool. All subjects were within normal limits of hearing. The DES was used to produce the various G environments. Subjects were seated in the DES cab and strapped in using seat restraints. Auditory stimuli were presented through headphones worn by the subjects. BSERs were recorded in a 1G environment in all six cardinal planes. The exposures used were +1G (on back), -1G (face down), +1G (left side), -1G (right side), +1G (upright position), and -1G (upside down). Each condition was replicated for a total of twelve blocks. A counterbalanced design among subjects was used for the order of G exposures. All exposures for a subject occurred in one day during the early afternoon requiring about 1.5 hours.

Subjects were instructed to close their eyes and relax throughout the duration of the stimulation period. In each trial, subjects were binaurally presented with auditory stimuli consisting of 1,000 broad-band clicks of 200 microseconds duration. These were presented at a rate of ten per second using alternation polarity. Click intensity was 65 db SL. Data collection time for each evoked response was 100 seconds with a rest period of at least one minute between trials. Subjects were given a five minute rest period after every fourth trial.

Electroencephalographic activity was obtained from the vertex (Cz). One mastoid was used for reference, and the other as a ground. Beckman silver/silver chloride biopotential miniature electrodes were used. Electrode resistances for all subjects were under 5k ohms. Amplification was carried out by a Grass Model P511 AC amplifier located in the DES cab, with an effective bandpass of 300 to 3,000 Hz and a gain of 50,000. The amplified signal was delivered through the DES slip rings to a Nicolet Model CA-1000 signal averager, which also generated the click stimuli for the BSER.

RESULTS

BSERs were elicited in all conditions. Representative BSERs from one subject are depicted in Figure 1. The latencies of four components were measured and their mean latencies and standard deviations appear in Table 1. These latencies correspond to those reported in the literature (6,10). As can be seen in Table 1, the latencies of the four peaks are clearly different but only small differences are seen within each peak's latencies as a function of orientation. Repeated measure ANOVAs were performed on the latency data separately for each peak. None of the analyses showed statistically significant differences for replication ($F = 1.61$, df 1/6, p 0.2511), and orientation ($F = 1.77$, df 5/30, p 0.1496). That is, the data is reliable but G orientation did not produce differences in the BSER latencies. Due to typical inter- and intra-subject variability amplitudes were not analyzed (6,10).

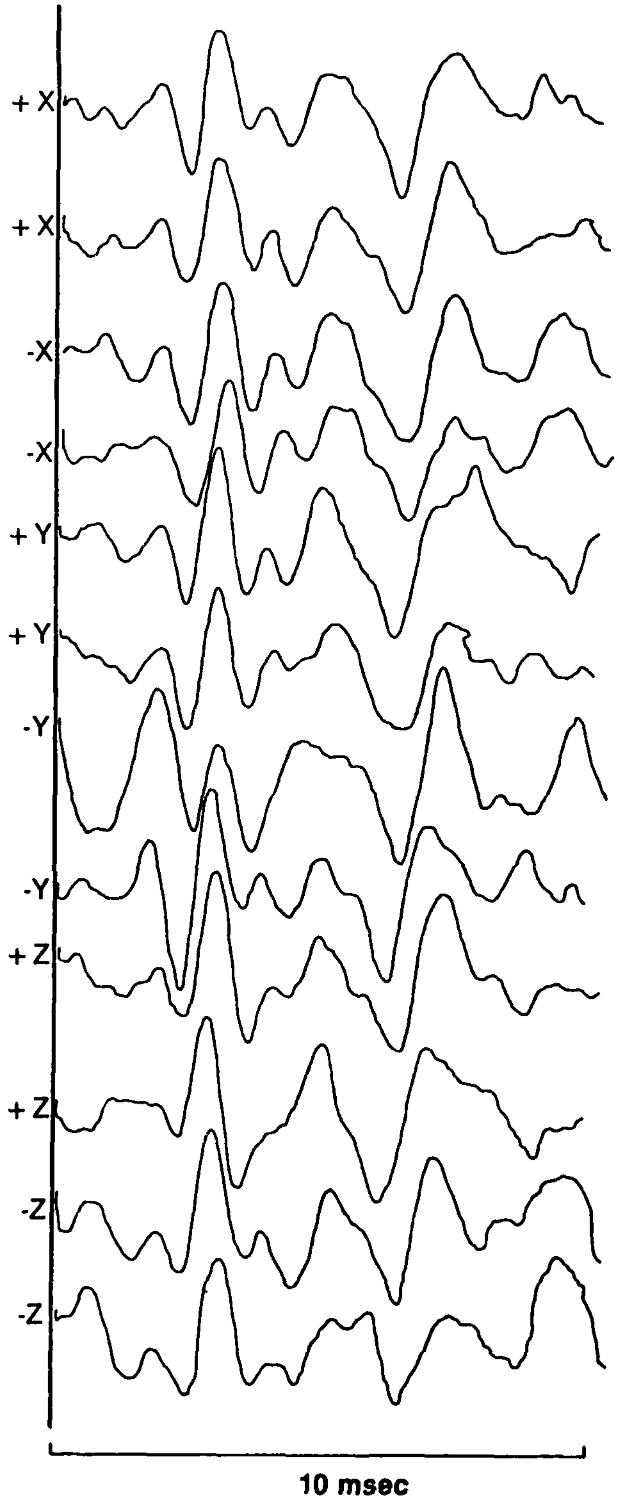

Figure 1. Represetative BSERs recorded from one subject during the six G orientations and two replications.

TABLE 1. MEAN LATENCIES (MSEC) FOR THE FOUR MEASURED PEAKS FOR ALL ROTATION CONDITIONS AND REPLICATIONS

	Peak 1	Peak 2	Peak 5	Peak 6
+X1	1.91	3.38	5.36	7.59
+X2	2.02	3.35	5.52	7.66
-X1	2.08	3.37	5.39	7.68
-X2	2.04	3.34	5.45	7.72
+Y1	1.84	3.25	5.41	7.53
+Y2	1.80	3.23	5.49	7.60
-Y1	2.02	3.28	5.41	7.71
-Y2	2.05	3.30	5.55	7.66
+Z1	1.93	3.32	5.51	7.68
+Z2	2.14	3.26	5.45	7.62
-Z1	1.97	3.35	5.41	7.54
-Z2	2.00	3.43	5.51	7.69
MEAN	1.98	3.32	5.46	7.69
STANDARD DEVIATION	0.09	0.06	0.06	0.06

DISCUSSION

The results of this study indicate that alteration of the nominal gravitoinertial vector on the otolith produced no electrically measurable change in the BSER. None of the static G conditions tested resulted in either increased or decreased latencies of any of the BSER peaks. Peaks that occur early, middle, and later in the BSER were analyzed so that interactions at the several structures thought to be represented in the BSER could be tested. Since the replications were the same for all G conditions, the lack of significance isn't due to trial-to-trial variability in the data. The data were reliable as is shown by the replication at each G load and also by the overall similarity of the peak latencies for each G condition.

Due to the different functions of the vestibular and auditory systems, it is not surprising that they operate independently of one another. The altering of G forces in this study was an attempt at altering the output of the otolith receptors of the utricle and saccule and not the angular acceleration receptors of the semicircular canals. The results of Wolf et al (13,14) which showed changes in the BSER to caloric stimulation was no doubt due to the effects of changes in the temperature of the auditory apparatus itself and not due to any interaction with the increased activity of the vestibular system. It is possible that dynamic effects due to acceleration could produce changes in the BSER. Harsha's (5) data using the Barany chair do not support this notion; however, his measurements were not taken during a dynamic state. Since the current study was completed, a follow-up study has been done by the authors to measure cortical evoked potentials to a dynamic state of angular acceleration. That study indeed showed an evoked potential to a dynamic state of angular acceleration on the vestibule, exclusive of any artifact (12).

On STS-4, Thorton found no difference in the audio evoked potential he obtained between astronauts not experiencing symptoms of SMS and those having symptoms of SMS (11). No ground controls on the same seven subjects were reported, however, so it is difficult to interpret these results. The additional variable in his experiment was the fluid shift experienced in the microgravity environment of the shuttle. Subjects in this experiment were not left in the altered 1 G environment long enough to appreciate a substantial fluid shift within the tissues. Not withstanding the fluid shift variable, the results of this study would predict the negative results obtained by Thorton.

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